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The governance of innovation diffusion – a socio-technical analysis of energy policy

C. Nolden[1,] Geography Department, College of Life and Environmental Sciences, University of Exeter, UK

Abstract. This paper analyses risk and uncertainty in the governance of UK energy policy and regulation. The UK's current planning system is unfavourable towards certain types of onshore renewable energy technologies. As a result, the UK is running the risk of retaining a comparatively small amount of its expenditure on the diffusion of renewable energy technologies both nationally and locally. This is contextualised within the broader framework of decarbonisation, transnational renewable energy targets and the lock-in associated with large infrastructures such as the energy system.

1 The context of UK energy policy

In the second quarter of 2011 renewables contributed 9.6% (7.86TWh) to the UK's electricity supply. This represents a 50% rise on 2010. The wind energy sector saw output rise 120% year on year, while hydro rose by 75% over the same period. Gas contributed 44% (down from 53% in 2010), coal 22% and nuclear 21% [1].

By 2020, around 1/3 of the UK's coal fired capacity, 2/3 of the oil fired capacity and nearly ¾ of the nuclear capacity, which amounts to around 30% of the UK's entire generating capacity [2], will be closed down due to age or the impact of the EU's large combustion plant directive [3]. For this same period, the UK has agreed to increase the share of energy demand to be covered by renewable sources to 15%, which will see the share of renewable electricity rise to around 30% [4]. By 2050, the electricity sector needs to be nearly entirely decarbonised in order to achieve the legally binding target of 80% CO2 emissions reductions on 1990 levels by 2050 [5, 6].

In order to achieve this transition towards a low-carbon and increasingly renewable energy system, investments ranging between £100bn and £200bn [6-8] will be required. The need to replace ageing electricity generation infrastructure and the pressure to expand renewable energy generation while reducing the overall carbon intensity of the UK economy is exacerbated by economic uncertainties, posing a considerable challenge to the UK economy and its energy sector in particular.

Energy policy in the UK has already witnessed various priority shifts in the last 40 year as Britain has swung from being a major oil and gas importer to being a producer and then moving back to being an importer, with import dependency set to increase to 46-58% by 2020 compared to 27% in 2009 [9].

The UK's principle dependency on gas was established in the 1990s as coal fired generation was phased out with the 'dash for gas' associated with privatisation and competition supplanting the post-war model of nationalisation and statutory policy. The result is that the achievement of policy objectives such as maintaining the security of supply has increasingly been placed in the hands of market forces [10].

2 Transition challenges

The achievements of the UK's competitive energy market are considered by many as the most brilliant policy success in the UK over the last 25 years [11] while others bemoan its failure to produce desired outcomes [12]. One of the less desired outcomes is that the UK's energy market remains characterised by lock-in. This implies that investments in the energy sector generally take several decades to pay off and utilities are reluctant to take ageing generation infrastructure off the grid as long as it is economically viable to continue operation due to the windfall profits this practice ensures [13, 14]. The incumbency of the system also increases the tendency to replace infrastructure on a 'like for like' basis. A diverse approach to scale, on the other hand, might introduce more flexibility into investment patterns, which would reduce the inherent irreversibility of many energy system investments [15].

The UK is therefore in the position where current decision-making in energy policy will determine the lock-in for the coming decades, particularly taking the legally binding 80% emissions reductions by 2050 on 1990 levels, as recommendations by the Committee of Climate Change [6], into account. The Long Term Electricity Network Scenarios commissioned by Ofgem (Office of Gas and Electricity Markets) provide options ranging from a centralised 'big transmission and distribution' scenario to a highly decentralised 'micro-grids' scenario [16].

The current tendency is towards a centralised scenario with a portfolio of centralised renewable energy options (primarily offshore wind), nuclear power stations and fossil-fuel with Carbon Capture and Storage [6]. This relates to lock-in associated with technological, institutional and social path dependency [16, 17]).

Centralised energy generation is a reflection of the economic development process and this trajectory is also indicative of social and economic values and behaviours and the nature of governance at local and national level. However, it is questionable whether it can provide for a more sustainable society and economy and lay the foundation for a transition. The problem with these technology options lies in their limited capacity to encourage more decentralised governance structures and service-based business models that could foster significant demand-side cuts in energy use [18]. The cost of setting up separate decentralised plant is high but if it is considered as part of a large scale transition of the UK electricity system it would be one project among many. A decentralised power grid will still need to rely on centralised power infrastructure, especially gas fired generation, to help balance supply and demand patterns within and between local areas [19].

3 The diffusion of renewable energy technologies

With the rediscovery of a 'role for government intervention' in the energy market [20], the last decade has seen several incentives being put forward and implemented to encourage the uptake particularly of renewable energy technologies. During this time period the Renewables Obligation has also undergone a transformation towards a feed-in tariff in all but name although competition appears to remain the overarching objective of energy policy, rather than the reduction of risk [21]. The UK government's stance on energy policy is therefore still to let the competitive market decide but it is increasingly accepting the need to slip back into the role of principle change agent by providing a framework capable of overtly influencing potentially negative effects of the invisible hand of the market [21].

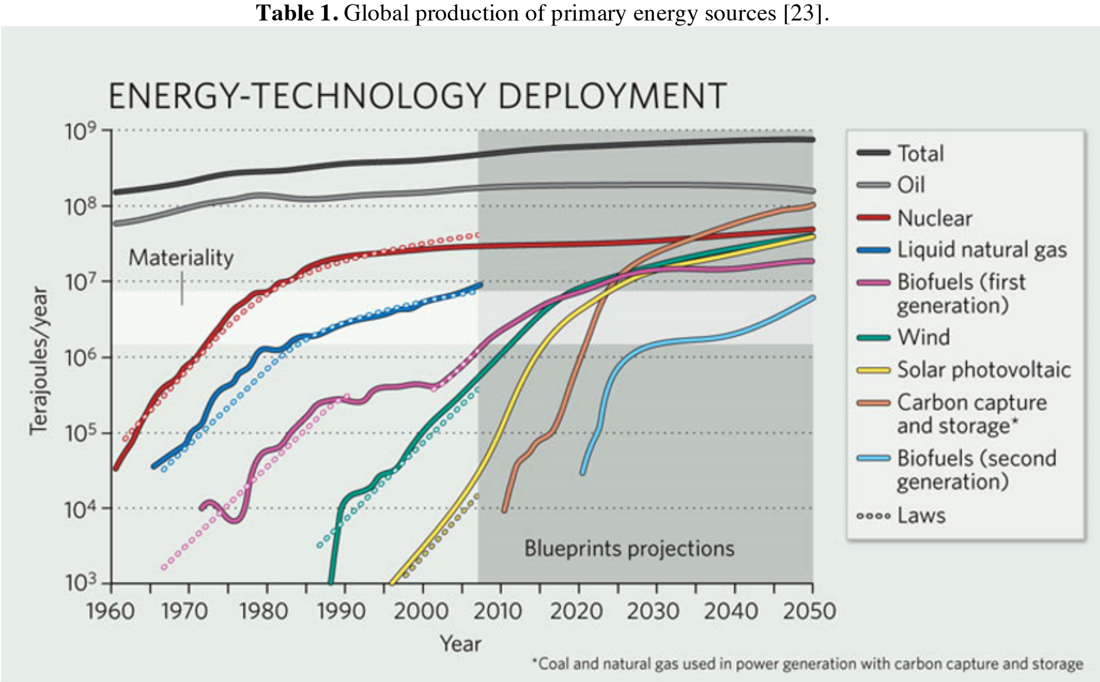
In general, however, the technical and political challenge of decarbonisation has been seriously underestimated [22]. Every major deployment of new energy technology has relied on some form of government support and the UK's challenge is to design energy policies capable of outperforming historical diffusion laws (see [23]). Certain technologies will need to be picked as winners, even if the choice of technology can be left to the market.

There are physical limits to the diffusion of technological innovation but Governments can accelerate deployment by designing policies to target specific technologies [23]. This provides space or 'niches' for technological incubation and development without the competitive pressure of markets dominated by incumbent technologies [24].

Niche development in the field of energy might entail the experimentation with various untested or novel technologies, in the process of which hands-on and contextualised knowledge emerges alongside locally applicable lessons. This innovation is then diffused through support regimes by networks of actors developing de-contextualised and more generally applicable rules and models independent from niche or local contexts [25, 26].

Policy support for niche development, such as feed-in tariffs, needs to be flexible as technologies move along the deployment scale from pilot projects to market interventions in order to cover the difference between energy generation costs and wholesale energy prices. The different banding of solar PV against wind, for instance, allows them to compete and once the threshold for 'materiality' is crossed, technology costs become the dominant factor as the unit costs should have fallen sufficiently so that any subsidies, in case they still remain necessary, are small [23].

Table 1. Global production of primary energy sources [23].



The diffusion of a portfolio of renewable energy technologies has the benefit of diversifying resources, but only once the technologies themselves have passed through the resource intensive production cycle. It also increases resilience to an extent that the energy system's adaptive capacity enables it to persist in changing frameworks and circumstances [27].

4 The co-evolution of technological and social innovations

This techno-economic dimension of the diffusion process, however, is not sufficient for the successful transition towards a low-carbon energy system as part of a low-carbon economy. Nevertheless, the UK's likely pathway of offshore wind, fossil-fuel generation with CCS and nuclear power [6] remains embedded within. CCS and nuclear power represent an end-of-pipe approach as they tackle carbon emissions at the point where electricity is generated without requiring any changes to the system. Offshore wind represents a continuity approach as it modifies a selected component of the system in that it is a technology that will require some balancing due to its volatile nature without disrupting the overall system architecture. Onshore wind and small-scale renewable energy technologies, on the other hand, represent more of a discontinuity approach as they have a combined capacity to entirely replace the centralised system, albeit at a highly localised/ island scale [14].

What is generally overlooked when it comes to the diffusion of decentralised renewable energy technologies in line with the discontinuity approach, is the social diffusion side of innovations. Solar PV, for example, started off in space technology where costs were less important but only through a process of co-evolution of technology and markets through investment grants, tax exemptions and regulatory support has the technology reached what might be termed ‘materiality’. Technological and social learning processes therefore enable adjustment of the technology as well as the social embedding to increase the chances of successful diffusion [28].

The challenge of deploying renewables, however, is increased by the different investment models required. Compared to conventional energy generation technologies, investment in renewable energy technologies is front loaded. This implies that the initial investment costs and sunk costs are relatively higher compared to the life-cycle costs of fossil-fuel plants, where a large share of the overall costs relate to the fuel itself, or in the case of nuclear power, to the decommissioning [29].

5 The UK renewable energy economy

The Renewables Obligation (RO) and the Feed-in Tariff (FiT) are the primary regulatory incentives designed to increase the implementation of renewables in the UK. The FiT avoids the problems one encounters when competing directly against established technologies in their area of strength as they enable market penetration through niches by addressing a market need which has gone unfilled by dominant technologies [30]. The RO is characterised more by competition between technologies, which has not always delivered anticipated results [12]. Both policies nevertheless constitute a coordinated assault on established electricity generation technologies.

The UK energy economics framework, however, remains heavily skewed in favour of incumbent technologies. The additional annual costs of renewable energy amount to around £30 per household while nuclear liabilities amount to around £350. New nuclear is also set to be excluded from additional costs they will impose on the network, an exemption which does not apply to renewable energy technologies [31].

Both the RO and the FiT have been successful at delivering technological diffusion in the areas they are arguably most favourable towards, onshore wind and solar PV. Compared to other European countries, however, their deployment rate remains relatively low. Even with the 2020 scenarios foreseeing a doubling of onshore capacity to 2.44 wind turbines per 100sq km [32], the UK will remain far behind the likes of Germany (5.95 WTs/100sq km) or Denmark (10.85 WTs/100sq km), countries that share similar land-use constraints as the UK [33]. The treatment that onshore wind energy receives within the UK planning system is therefore inhibiting a sustained technological diffusion despite the RO and the FiT providing incentives for technological deployment.

This is further proof of the UK’s centralised generation lock-in, which is resulting in the UK lagging behind many other northern European countries in the location of electricity generation capacity close to the end consumer [34]. With current governance structures this is unlikely to change considerably in the near future and this development has been hampered further by the lack of incentives for local authorities to engage in energy generation. Nevertheless there remains scope for sub-national institutions to play a greater role in decentralisation. So far however, only local authorities in Woking and London have proven successful and these examples may indicate the difficulties associated with developing capacities for local authorities in the UK to influence the shape of local energy systems [19, 35]. The failure to realise these considerable potentials for more renewable energy development potentially amounts to system failure [36].

The success of other countries’ cumulative causation processes relating to the diffusion of renewable energy technologies lies in the formation and sustaining of markets. This is achieved by giving investors ‘benefits that are powerful (to provide strong incentives and to compensate for the inherently large uncertainties involved), predictable (to reduce inherent uncertainties to manageable level) and persistent (to allow for long life times of the equipment and a long learning period)' [37].

On the other hand, the UK is world leader in offshore wind with a capacity installed equal to the installed capacity of the rest of the world put together [38]. This partly relates to the prioritisation that offshore wind receives by the Department of Energy and Climate Change, which is arguably '95% offshore' [39] as well as the indirect prioritisation through the planning system. The planning for developments exceeding 50MW is decided by the Secretary of State according to Section 36 of the Electricity Act 1989 [40], rather than local councils.

6 Renewable energy and decarbonisation

The UK's focus on offshore wind at the centralised scale and solar PV at the decentralised scale is unnecessarily expensive, particularly regarding the cost per unit of decarbonisation. This narrow technological focus might even have knock-on effects in other areas by reducing competitiveness and welfare. The total cost of this trajectory will amount to £32bn under the RO, £3.6bn under the FiT and another £18.7bn relating to other policies and measures between 2011 and 2020. The cost per tonne of carbon saved amount to around £130 under the RO and £460 under the FiT, compared to £14 per tonne of carbon saved under the technology neutral EU ETS [41].

At the same time, the cost of electricity from CCGT has also doubled between 2006 and 2010 from £42/MWh to £80/MWh. Similarly, the cost of offshore doubled between 2005 and 2010 due to rising costs of materials, commodities and labour costs, currency movements, increasing prices for turbines over and above the cost of materials due to market conditions and engineering issues, the increasing depth and distance of more ambitious projects affecting installation, foundation and operation and maintenance costs, supply chain constraints, notably in vessels and ports and planning and consenting delays. Baring these difficulties in mind, the best guess for the cost of offshore wind power for the mid 2020s is around £115/MWh [42]. This compares to onshore wind as 'the lowest cost large scale, commercially available low carbon generator applicable in the UK' [42].

It therefore appears as though the competitive energy market in the UK has picked offshore wind and solar PV as winners, despite its technological neutrality. Their diffusion trajectories are unlikely to provide sufficient capacity for learning to reduce the cost of deployment. Offshore wind, in particular, is likely to maintain a cost profile more akin to experimental marine technologies than other renewable energy technologies [41], despite the UK government objective to reduce the cost of offshore wind to £100/MWh by 2020 [43].

7 Social embedding of renewable energy technologies

In line with its narrow technological choice, government is moving towards a centralised planning approach, which arguably damages the ability of the market to deliver cost-effective decarbonisation solutions [40]. One of the crucial points mentioned above is that the diffusion of onshore wind, which comes at around half the cost of onshore wind, is inhibited by the planning system. It is estimated that 6.8GW of onshore wind are currently being held up in the planning process and the historical approval rate for onshore wind stands at around 40%, which could be increased to 60% with appropriate planning reforms. Crucially, the argument in favour of onshore wind entails the demand for communities to have a stake in determining the appropriate compensations in return. This would still be cheaper than developing offshore, thereby providing savings for society overall as it will also increase the speed at which projects can be granted planning consent. What is required is an effective mechanism to trade off the costs with an appropriate share of the benefits associated with giving local communities greater say over local renewable energy deployment [41].

Increasingly, this is also a view reflected by the UK government as it is currently demanding 'a new relationship between wind farms and the communities which host them' [44], which partially reflects the realisation that achieving the renewable energy targets would require something in the line of a tripling of onshore wind capacity [45]. With more favourable conditions towards the deployment, the cost of onshore wind is expected to drop to an extent that it will be able to compete against coal gas and nuclear without subsidies by 2016, as every doubling of installed capacity has seen prices drop by 7% due to economies of scale and supply chain efficiencies. In real terms, the levelised costs reveal that the cost of onshore wind has dropped from €200/MWh in 1984 to €52/MWh in 2011 [46].

This might reflect the increasing acceptance that truly sustainable governance of the system of energy provision requires learning, experimentation and iteration, both of the socio-ecological and the socio-technical system. By socially embedding technological diffusion processes, the sometimes fierce resistance that particular developments face from various stakeholders including actors that are not direct users of the technology can be considerably reduced. This resistance is associated with the societal transformation/ impact often associated with the technologies, conflicting visions about their consequences and desirable path to follow among different stakeholders. Purely technological projects that do not take this dimension into account therefore tend to fail due to inappropriate considerations of the societal diffusion side of innovations [30].

In other countries, feed-in tariffs have hereby played a crucial role in the development of both a relatively low-cost renewable energy portfolio over time [12] as well as a more socially embedded energy system. The tariff levels can be easily adjusted to reflect downward pricing pressures in line with the learning, diffusion and adaptation process. FiTs have been heavily criticised for their reliance on government, rather than the market to determine the appropriate level of tariffs and with poor economic forecasting there is the danger of high tariffs driving technology costs up to the tariff level, which can result in ‘gold rushes’ or ‘boom and bust’ cycles [47].

However, thanks to the underlying logic of both FiTs and renewable energy technologies, they are easy to understand in principle by both investors and finance providers. As a result, they attract greater plurality and engagement of market participants, including individuals, communities, businesses as well as specialist developers, investment funds and utilities [47].

9 Conclusion

Both the RO and the FiT have succeeded in promoting two distinctly separate renewable energy technologies, both of which are prohibitively expensive regarding decarbonisation: offshore wind and solar PV. On the other hand, these technologies arguably range quite low on the diffusion of innovations curve and various forms of subsidies will be required for a very long period (10+ years) to ensure that these technologies reach grid parity. Offshore wind in particular is still very much in the pre-commercial stage and learning effects are unlikely to drive this technology towards grid parity any time in the near future.

At the same time, decentralisation and increasing government intervention in the UK energy market is providing the opportunity for greater engagement with energy at the sub-national level. This might reflect the desire to improve energy policy’s engagement potential as energy policy in other countries such as Germany and Denmark has enabled large numbers of individuals to take part in climate change action and the development of socio-ecological resilience by investing in renewable energy capacity.

This is where the real failure of UK energy policy lies. Its commitment to market liberalisation creates unpredictabilities due to a lack of stability over time. It also lacks consistency concerning the co-evolution of liberal market principles, environmental principles and energy security ambitions.

However, as long as the UK is lacking an industrial production base for renewable energy technologies it remains to be seen whether decarbonisation targets can go hand in hand with a more decentralised approach to electricity generation.

References

1. DECC, *Digest of UK Energy Statistics*, (Department of Energy and Climate Change, London, 2011) http://www.decc.gov.uk/assets/decc/ 11/stats/publications/dukes/2307-dukes-2011-chapter-5-electricity.pdf
2. R. Soames, CEO of Aggreko, speech before the Scottish Parliament, (2010) < http://link.brightcove.com/services/player/bcpid640957304001?bctid=676265059001 >
3. European Parliament, *Directive 2001/80/EC*, Official Journal of the European Communities, L 309/1 (Brussels, 2001)
4. HM Government, *The UK renewable energy strategy* (TSO, Norwich, 2009)
5. House of Commons, *Energy and Climate Change – Sixth Special Report: Government Response* (2011) http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/1448/144802.htm
6. CCC, *The Fourth Carbon Budget* (London, Committee on Climate Change, 2010)
7. Ofgem, *Press Release*, R/39 (2009)
8. REA, *17,000 new solar jobs since April – but uncertainty must end* (Renewable Energy Associattion, 2011) http://www.r-e-a.net/info/rea-news/260111FITreview
9. DECC, *Annual Energy Statement – DECC Departmental Memorandum*, (DECC, London, 2011)
10. D. Helm, *Energy, the State and the Market: British Energy Policy since 1979*, (Oxford University Press, Oxford, 2004)
11. P. Noel, and M. Pollitt, *Don't lose power* (2010) http://www.eprg.group.cam.ac.uk/wp-content/uploads/2010/07/NoelPollitt_UKEnergyPolicy_ParliamentaryBrief_100723.pdf
12. C. Mitchell, *The Political Economy of Sustainable Energy* (Palgrave MacMillan, Basingstoke, 2008)
13. G. Unruh, Energy Policy **28** (12), 817 (2000)
14. G. Unruh, Energy Policy **30** (4), 317 (2002)
15. F. Fielder, The Electricity Journal **9** (4), 62 (1996)
16. G. Ault, D. Frame, N. Hughes, *Final Report for Ofgem's LENS Project* (Ofgem, London, 2008)
17. S. Jacobsson, A. Johnson, Energy Policy **28**, 625 (2000)
18. P. Vaze, S. Tindale, *Repowering Communities – Small-scale solutions for large-scale problems* (Earthscan, Abingdon, 2011)
19. J. Watson, P. Devine-Wright, Centralisation, decentralisation and the scales in between: What role might they play in the UK energy system in *The Future of Electricity Demand: Customers, Citizens in a Loads*, edited by M. Pollitt, T. Jamasb, (Cambridge University Press, Cambridge, 2010), pp. 280-297
20. DECC, *Energy Markets Assessment* (DECC, London, 2010), pp. 9
21. B. Woodman, C. Mitchell, Energy Policy **39**, 3914 (2011)
22. R. Pielke jr, T. Wigley, C. Green, Nature **452,** 531 (2008)
23. G. Kramer, M. Haigh, Nature **462**, 568 (2009)
24. T. Stenzel, A. Frenzel, Energy Policy **36** (7), 2645 (2008)
25. L. Coenen, R. Raven, G. Verbong, *Local niche experimentation in energy transitions:a theoretical and empirical exploration of proximity advantages and disadvantages* (CIRCLE Electronic Working Papers, Lund, 2009)
26. F. Geels, M. Hekkert, S. Jacobsson, Technology Analysis & Strategic Management, **20** (5), 521 (2008)
27. B. Smit, J. Wandel, Global Environmental Change **19**, 282 (2006)
28. G. Verbong, R. Mourik, R. Raven, R. *Towards integrated methodologies for assessing and promoting the societal embedding of energy innovations*, (ASRELEO Conference paper, 2006)
29. E. Knight, N. Howarth, *Clean energy technology and the role of non-carbon price based policy: an evolutionary economics perspective* (CCEP Working Paper 2, 2011)
30. J. Weiss, B. Dale, Industrial Marketing Management **27**, 293 (1998)
31. C. Mitchell, *Who is in charge of Britain's energy policy?*, (2012) http://www.guardian.co.uk/environment/2012/feb/28/britain-energy-politics

32. BWEA, *International Comparisons: Turbine Densities and Capacity Factors*, (2011) http://www.bwea.com/pdf/publications/RenewableUK_Turbine_Density_Study.pdf
33. M. Pollitt, Cambridge Working Paper in Economics, **1007** (2010)
34. S. Roberts, Energy Policy **36** (12), 4558 (2008)
35. H. Bulkeley, K. Kern, Urban Studies **12**, 2237 (2006)
36. A. Johnson, S. Jacobsson, The Emergence of Growth in Industry: A Comparative Analysis of the German, Dutch and Swedish Wind Turbine Industries, in *Transformation of Development: Schumpeterian Perspectives*, edited by S. Metcalfe, U. Canter (Physica/Springer Heidelberg, 2001)
37. S. Jacobsson, A. Bergek, Transforming the Energy Sector: The Evolution of Technological Systems in Renewable Energy Technology, in *Governance for Industrial Transformation – Proceedings of the 2003 Berlin Conference on the Human Dimension of Global Environmental Change*, edited by K. Jacob, M. Binder, A. Wiezorek, (Environmental Policy Research Centre, Berlin, 2004), pp. 227
38. BWEA, *10 facts about UK offshore wind*, (2012) http://www.bwea.com/offshore/
39. N. Farringdon, Personal communication (2011)
40. HM Government, *Electricity Act 1989* (TSO, Norwich, 1989)
41. S. Moore, *2020 Hindsight – Does the renewable energy target help the UK decarbonise?* (Policy Exchange, London, 2011)
42. P. Greenacre, R. Gross, P. Heptonstall, *Great Expectations: The cost of offshore wind in UK waters – understanding the past and projecting the future*, (UKERC, London, 2010), pp. vii
43. DECC *UK Renewable Energy Roadmap*, (DECC, London, 2011)
44. DECC *Charles Hendry sets out new approaches to onshore wind: Westminster Hall debate*, (2011) http://www.decc.gov.uk/en/content/cms/news/hendry_onshore/hendry_onshore.aspx
45. L. Gray, *'Bribes' for areas that accept a wind farm* (2011) http://www.solarpowerportal.co.uk/blogs/blown_away_energy_minister_backs_wind_with_bribes/
46. A. McCrone, *Onshore wind energy to reach parity with fossil-fuel electricity by 2016* (Bloomberg New Energy Finance, 2011) http://bnef.com/PressReleases/view/172
47. J. Johns, Renewable support mechanisms: the transition to low carbon, in *Renewable energy country attractiveness indices* (Ernst & Young, 2011) http://www.ey.com/Publication/vwLUAssets/Renewable_energy_country_attractiveness_indices_-_Issue_28/$FILE/EY_RECAI_issue_28.pdf